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Texas Agricultural Experiment Station

A. B. CONNER, DIRECTOR

COLLEGE STATION, BRAZOS COUNTY, TEXAS

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DIVISION OF AGRONOMY

Irrigation Requirements of Cotton and Grain Sorghum in the Wichita Valley of Texas

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

T. O. WALTON, President

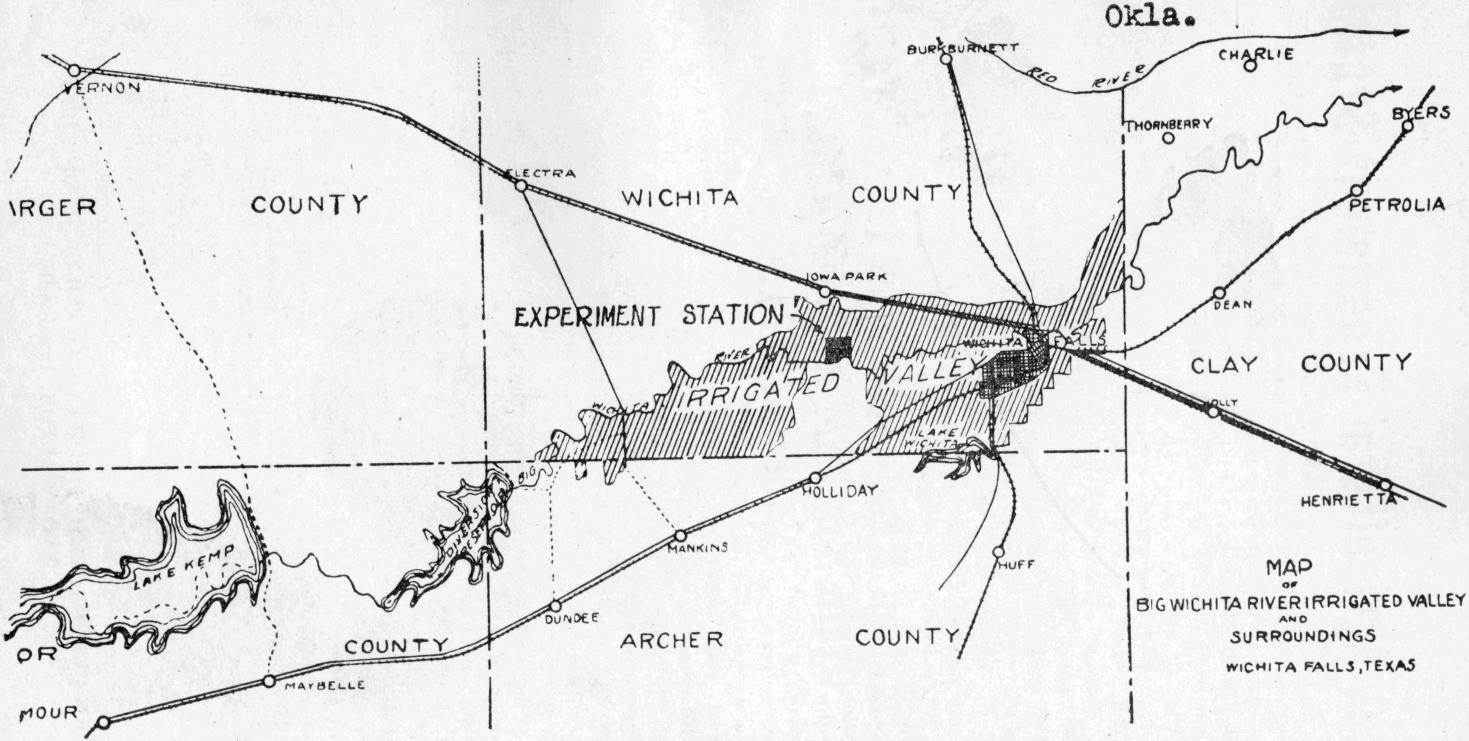

Fig. 1. Showing location of the Wichita Irrigated Valley of Texas.

In 1932, the Iowa Park Substation began irrigation experiments to determine the optimum amount of water for the production of cotton and grain sorghum in the Wichita Irrigated District, where irrigation is practiced as a supplement to rainfall. In this region, with an average yearly rainfall of 30.14 inches, the average rainfall during the growing season for cotton is 13.60 inches and for grain sorghum 15.82 inches.

The irrigation work was done on Miller loam soil, which is productive and representative of the irrigated soils in the Wichita Valley. The amounts of irrigation water used ranged from 2 to 34 acre inches, in addition to the rainfall during the growing season. The work was conducted five years, 1932-36.

The largest yields of cotton were obtained where 28 to 32.40 acre inches of water, including the rainfall, were used during the growing season; the average was 16 inches of irrigation water. For the five years the highest average yield was obtained on plats receiving a total of 30 inches of water. The total amount of water received by a plat is the water applied in pre-irrigation three weeks before planting and that applied by irrigation up to harvest, plus whatever rainfall occurs during this period. The yield decreased as the amount of water was decreased or increased from 30 inches. This indicates that 30 acre inches is probably the optimum amount of water for cotton in the Wichita Valley. On account of the variable season different amounts of irrigation water are needed in different seasons and the experienced grower determines from the color of the plants when to apply the water. It has been observed that the cotton plant needs irrigation when the color changes from the normal green to a bluish green.

Grain sorghum apparently can use considerably more water than cotton, probably because it produces a larger vegetative growth. The largest average yields were obtained from the use of about 39 inches although satisfactory yields were obtained where the amount of water ranged from 34 to 39 acre inches.

The amount of water required by cotton and grain sorghum is influenced considerably by temperature, humidity, and evaporation. Usually more water is required by these plants in hot, dry years than in years with more favorable rainfall and temperature.

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IRRIGATION REQUIREMENTS OF COTTON AND GRAIN SORGHUM IN THE WICHITA VALLEY OF TEXAS

C. H. McDowell, Superintendent, Substation No. 16,
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The proper use of irrigation water is perhaps the most fundamental problem in crop production in regions where crops are grown under irrigation. Studies on irrigation in various parts of the world have shown that irrigation practice is influenced by many factors, among which are kind of crop grown, nature of soil, amount and distribution of rainfall, temperature, and evaporation. It is known that these factors or conditions vary widely in different regions, and for this reason it is necessary to know something of these conditions in a given region in order to develop a suitable and rational irrigation practice.

The Wichita Valley Irrigation District was established in 1923. Since there are no other irrigation areas nearby, and since no information on irrigation was available relative to the conditions found in this district, an immediate demand arose for information on the proper use of water for various crops under irrigation. Texas Substation No. 16 was established at Iowa Park, near the center of the District, in the fall of 1924 for the purpose of studying crop production under irrigation. Field experiments to determine the optimum amount of water for the normal production of cotton and grain sorghum were started in 1932. The results of these experiments are reported in this bulletin.

DESCRIPTION OF THE WICHITA IRRIGATED VALLEY

The Wichita Irrigated Valley embraces an area of approximately 80,000 acres of irrigable land, of which 35,000 acres are actually under irrigation. The irrigated area lies between the Diversion Reservoir and the Clay County line, and is almost entirely within Wichita County, as shown in Figure 1.

Abundant storage of water for irrigating the Valley is held in Lake Kemp, situated about 50 miles west of Wichita Falls, which has a storage capacity of 560,000 acre feet. Lake Kemp is connected with a large Diversion Reservoir, located about 35 miles west of Wichita Falls, with a storage capacity of 40,000 acre feet. All of the water for irrigation is taken from these two lakes and is carried by gravity through large canals to all parts of the irrigated land of the Valley.

Soils

The predominating soils of this area are derived from the Permian Red Beds, residual in formation, and are classified according to soil series as Miller, Yohola, Ford, Calumet, Wichita, and Vernon. Carter (5).

These soil series are further classified as very fine sandy loam, silty clay loam, loam, clay loam, and clay. These soils are reasonably well drained, fairly retentive of moisture, fertile, and productive under irrigation. The field experiments conducted at Substation No. 16 were on soil classified as Miller loam, which is moderately well drained, but crusts badly on the surface following rainfall and irrigations.

Weather and Climatic Conditions

The climatic conditions of this area are similar to those of large areas of the State, with dry weather usually prevailing during the summer months, and with uneven distribution of rainfall, which makes it necessary to supplement the rainfall with irrigation to insure normal crop production. The average annual rainfall for this region is fairly adequate for crops, but because of its uneven distribution crop production is

Table 1. Precipitation, inches

Month	1932	1933	1934	1935	1936	Average	
						5-year, 1932-36	11-year, 1926-36
January	3.09	.55	.52	.41	1.21	1.16	1.19
February	4.51	.93	1.06	1.33	.11	1.59	1.57
March	.30	4.17	4.21	2.97	.30	2.39	2.30
April	1.95	.71	1.22	1.41	1.29	1.32	1.87
May	2.11	7.82	2.93	9.70	3.69	5.25	4.34
June	2.73	.25	1.42	4.40	.67	1.89	2.93
July	3.09	.28	.48	1.93	.85	1.33	3.20
August	5.19	5.98	2.40	1.07	0	2.93	2.30
September	2.49	.78	4.13	3.63	12.56	4.72	3.36
October	1.39	.26	.64	2.79	1.89	1.39	3.32
November	.15	1.67	5.62	1.68	.16	1.86	1.64
December	6.09	2.65	.07	1.18	.62	2.12	2.12
Total	33.09	26.05	24.70	32.50	23.35	27.95	30.14

Table 2. Mean mean temperatures, degrees F.

Month	1932	1933	1934	1935	1936	Average	
						5-year, 1932-36	11-year, 1926-36
January	44.5	50.3	45.7	47.7	39.5	45.5	42.8
February	54.5	44.0	47.5	48.8	40.9	47.1	47.9
March	51.4	58.0	53.3	62.1	60.0	57.0	55.5
April	66.1	65.1	65.8	64.1	64.5	65.1	64.8
May	71.6	73.5	73.1	69.3	74.1	72.3	71.9
June	80.6	80.6	85.6	79.1	83.2	81.8	81.2
July	84.1	85.2	88.3	83.9	86.3	85.6	84.6
August	83.5	82.5	88.0	85.4	88.0	85.5	84.7
September	74.9	82.3	76.0	72.1	78.1	76.7	77.4
October	64.1	68.8	69.3	67.4	61.8	66.3	66.9
November	49.9	55.5	57.5	49.6	51.0	52.7	53.0
December	39.7	48.8	45.8	43.0	47.9	45.0	44.4
Mean	63.7	66.2	66.3	64.4	64.6	65.0	64.6

11-year extremes, 1926-36, inclusive:
Maximum 112—August 1936.
Minimum —5—January 1930.

Table 3. Evaporation*

Month	1932	1933	1934	1935	1936	Average	
						5-year, 1932-36	11-year, 1926-36
January	1.766	2.034	1.824	1.787	1.447	1.772	1.664
February	1.851	2.031	2.391	2.478	2.203	2.191	2.261
March	5.579	4.350	4.164	4.210	5.243	4.709	4.541
April	6.569	6.676	4.844	5.049	5.801	5.788	5.776
May	6.899	6.532	6.326	5.115	6.065	6.187	6.479
June	7.575	8.786	10.035	6.282	8.515	8.239	8.387
July	10.442	8.480	10.413	7.653	8.923	9.182	9.007
August	7.894	6.734	9.664	7.998	9.176	8.293	8.272
September	4.716	6.055	6.193	4.373	5.331	5.334	6.156
October	4.951	4.911	4.777	3.798	3.515	4.390	4.452
November	2.846	2.840	3.028	1.980	2.238	2.586	2.744
December	1.268	1.924	1.861	1.536	1.531	1.624	1.750
Total	62.356	61.353	65.520	52.259	59.988	60.295	61.489

*from a free-water surface.

reduced materially where irrigation is not practiced. The mean annual rainfall for this area was 30.14 inches for the 11 years 1926-36, inclusive, as recorded at Substation No. 16 (Table 1). The average mean temperature (Table 2) was 64.6 degrees F. for the same period, with an extreme maximum of 112 degrees in August, 1936, and an extreme minimum of —5 degrees in January, 1930. The average annual evaporation (Table 3) from a free-water surface for the 11-year period was 61.489 inches, which indicates that the loss of moisture from evaporation alone is more than twice the amount of rainfall.

REVIEW OF LITERATURE

History of Irrigation in Texas

Nagle and Fortier (17) state that irrigation in western Texas antedates any records so far found, and that it is probable that in no part of the United States is the practice older. Coronado on his journey northward in the early part of the sixteenth century found well-established systems of irrigation in the vicinity of El Paso. Ancient irrigation systems of great extent were built centuries ago by the Yuma Indians on the Pecos River in the vicinity of Pecos and Grand Falls. In the vicinity of Toyah Springs evidence is found that these waters were used for irrigation purposes long before the first white man found his way there. At San Antonio, where the Franciscan fathers founded their missions, irrigation canals were constructed by the Indians as early as 1716. Among these early constructed ditches may be mentioned those at the Missions of Concepcion, Alamo, San Jose, San Juan, Espada, and San Pedro.

Irrigation of Cotton

Considerable literature is available on the subject of the duty of water, or water requirements of cotton under irrigation, in the states of California, New Mexico, Arizona, and Nevada, with some reference to irrigation in Texas.

Marr and Smith (15) define the term "duty of water" as the relationship between the quantity of irrigation water and the area of land irrigated, expressed in two ways: (1) the relation between the size of the irrigation stream (measured in miners' inches, gallons per minute, or cubic feet per second), and the area served, and (2) the quantity of water (measured in acre feet) per acre per year. The duty of water is said to be "low" when the water is used wastefully while in a relatively large measure; it is said to be "high" when the water is used efficiently or in relatively small quantities per acre. Formerly studies on duty of water were treated purely from the standpoint of engineering, as of interest mainly to courts and those who were responsible for the division of public water supplies.

In actual irrigation practice, Marr and Smith (15) report that on 13 different farms located on Maricopa sandy loam soil in the Salt River Valley of Arizona, the yield of cotton increased in a general way as the amount of irrigation water was increased. The average yield of cotton increased from 175 pounds per acre where 1.22 acre feet of water was applied to 650 pounds per acre where 3.5 acre feet were applied.

Marr and Hemphill (14) studied the amount of water needed by the cotton crop in the southwestern United States. In the Salt River Valley of Arizona, the quantity of water used for cotton varied from 2 to more than 4 acre feet. At the United States Field Station, Sacaton, Arizona, in 1923, Pima cotton yielded 1391 pounds of seed cotton per acre while Acala yielded 2269 pounds with an application of 2 acre feet of water per acre. In the Imperial Valley of California, the quantity of water used ranged from 2.5 to 6 acre feet; the larger quantity of water was needed on very sandy soils and the smaller amount on fertile, sandy loam soils with a larger water-holding capacity. In the upper Rio Grande and Pecos Valleys in New Mexico and Texas, from 8 to 20 acre inches of water is required. In the Lower Rio Grande Valley of Texas, 3 to 21 acre inches of water is required, depending on the amount and distribution of rainfall. In the latter region one to four irrigations are given to the cotton crop.

Beckett and Dunshee (2) found that the yield of cotton increased in general as the amount of irrigation water was increased on sandy loam in southern San Joaquin Valley of California. During the five years, 1926-30, cotton that received 22.6 acre inches of water in three irrigations produced an average yield of 603 pounds of lint per acre, while cotton that received 38.6 acre inches in seven irrigations produced 1034 pounds of lint per acre.

In New Mexico, Curry (8) conducted experiments from 1925-30 to determine the irrigation requirements of Acala cotton in the Mesilla Valley. He reported that cotton has a wide adaptation with respect to amounts of irrigation water applied. He found that 18.9 to 21.5 acre inches of water applied in four to five irrigations produced almost as large yields of cotton as 41 acre inches applied in ten irrigations.

Hawkins (12) in Arizona found that 2.5 to 3 acre feet of water produced four bales of cotton per acre in 1934, while from 3 to 4 acre feet was required to produce three bales per acre in 1933.

Fortier and Young (11) conducted experiments to determine the amount of water required to produce cotton in the Pacific Slope Basins. They report that the average maximum production of 2.06 bales per acre was obtained from 3.46 acre feet of water applied in seven irrigations during the years 1926-30. This amount of water included a 6-inch pre-irrigation and rainfall.

At the New Mexico Station, Bloodgood and Curry (1) applied 20 acre inches of water to cotton in three irrigations and obtained a yield of 819 pounds of lint per acre. They state that the general practice of irrigating cotton in the Mesilla Valley is to apply about 18 inches of water in three or four irrigations.

McDowell (16) reported on growing cotton under irrigation in the Wichita Valley of Texas for the years 1932 and 1933. He stated that the largest yield of cotton, 450 pounds of lint per acre, was obtained from 28.54 acre inches of water. When the water was increased to 31 acre inches the yield was reduced to 427 pounds of lint per acre.

Fortier and Young (10) observed that in growing cotton at the New Mexico Station, on adobe soil overlying coarse sand, a total of 1775 pounds of seed cotton per acre was obtained when 33 acre inches of irrigation water was applied in five to six irrigations, and that when the water was increased to 37 inches the yield was reduced as much as 200 pounds of seed cotton per acre. With cotton grown on worn-out fine sandy soil at the Medina Project, Medina County, Texas, a maximum production of 260 pounds of lint per acre was obtained with 17 acre inches of water. Near Mercedes, Texas, on sandy loam soil, as much as 625 pounds of lint cotton per acre was obtained with 22 acre inches applied in one to six irrigations.

Cook and Martin (9), Camp (4), Marr and Hemphill (14), and Hudson (13) discuss in detail irrigation methods best suited to cotton. They state that the general appearance of the cotton plant is a good index as to the time to apply water. Neither the apparent quantity of moisture in the soil, nor the date of previous irrigation, nor the quantity of water previously applied can be accepted generally as a safe basis upon which to determine the time for subsequent irrigation. According to present information the appearance of the crop offers the only dependable guide in this regard.

The foundation for maximum production of cotton will be laid if only sufficient water is given the plants during the early stage of development to keep them in a healthy growing condition. Wilting of some of the plants in the middle of the day during the early growth is not harmful and is not conclusive evidence that a general irrigation is needed.

When cotton plants begin fruiting and flowering they need and use the maximum quantity of water, and the subsequent irrigations should be frequent and heavy enough to prevent any serious wilting during the middle of the day. When the plants indicate a need for irrigation, neglect for only a few days may result in serious loss from shedding of young squares and bolls. Careful observations have shown that the color of the foliage in the dry spots appears somewhat darker, with a slightly bluish tinge, so that cotton in need of water can be recognized even from a distance. This color change is noted even before the plant shows signs of wilting, and should be a definite warning that water is needed. Another sign upon which growers of upland cotton rely is the color of the terminal growth. When in a thriving condition the plant will ordinarily show 3 to 4 inches of a tender, light green stem between the terminal bud and the reddish coloring of the stalk. A rapid extension of this reddish coloring toward the terminal bud shows a checking of growth and indicates the need of irrigation. When the flowers can be seen extending above the terminal buds of the plants, and a decided yellow color is noted over the field, it is evident that irrigation has been postponed too long. An excess of water is usually indicated by a waxy sheen to the foliage, large coarse leaves, and excessive terminal growth.

Irrigation of Grain Sorghum

In the Sacramento Valley of California, Beckett and Huberty (3) found that the net irrigation requirement of Dwarf milo exceeded 12 acre inches, on a brown soil, under the normal seasonal rainfall of 15 inches, indicating a total water requirement of fully 27 acre inches. In 1913, with a seasonal rainfall of only 8.74 inches, as much as 18 acre inches of irrigation water was necessary to secure a maximum production of 1842 pounds of grain per acre. In 1922, with a seasonal rainfall of 16.63 inches, an addition of 13.6 acre inches of irrigation (making a total of 30.23 inches) was required to produce a maximum yield of 5747 pounds of grain per acre.

Fortier and Young (10) reported that under conditions equally favorable throughout the semi-arid Southwest, the yields of sorghums were greater when the effective rainfall was supplemented by irrigation water, and that this crop required 2.5 to 3 acre feet of water to produce maximum yields.

Marr and Smith (15) reported on grain sorghums grown in the Salt River Valley, Arizona, and found that Dwarf milo on a clay loam type of soil produced a maximum yield of 3000 pounds of grain per acre, with a total application of 1.65 acre feet irrigation water in four irrigations. On the same type of soil, when only 1.13 acre feet of water was applied in three irrigations, the production was lowered to only 2250 pounds of grain per acre. On a sandy loam type of soil, a maximum yield of 2500 pounds of grain per acre was obtained with only .75 acre foot of water applied in four irrigations, and only 2000 pounds of grain per acre was produced when 2.20 acre feet was applied in four irrigations.

Fortier and Young (11) reported on growing Dwarf milo on Yohola fine sandy loam, in the Sacramento Valley, California, and found that a maximum yield of more than 5000 pounds of grain per acre was obtained when irrigation water was applied in amounts ranging from 1.39 to 1.93 acre feet. Excessive applications of 2.14 to 2.23 acre feet of water lowered the production of grain to less than half, or 2500 pounds per acre.

Bloodgood and Curry (1) reporting on growing sorghum in the Mesilla Valley, New Mexico, stated that a total of 14,156 pounds of forage was produced with 31.6 acre inches of water applied in five or six irrigations. This test was grown on medium heavy soil type.

METHOD OF ANALYZING THE DATA

The data were analyzed each year separately and a second degree parabolic curve was fitted by the method of least squares to the actual plat yields of cotton and grain sorghums. The equation[1] $\overline{Y} = a + bX + cX^2$ was computed in fitting the curve to the data. The correlation index, which is an abstract measure of the closeness of agreement between the observed yields and the fitted curve, was computed.

The 5-year average relative yields of cotton and grain sorghums were compared on a percentage basis in order to reduce seasonal influences to a minimum. The sum of the yields of all water levels secured in any one year represents the total production for that year and was given a value of 100 per cent. This sum was divided into the yield of each rate of water application for that year and the relative yield was expressed in terms of percentage. The applications of water were grouped into intervals of 2 acre inches with their corresponding average relative yields expressed in pounds. The frequencies of observations varied slightly for each interval, with an average frequency of three observations for each water interval. A second degree parabolic curve was fitted by the method of least squares to the average percentage yields, and the correlation index was computed. The percentage ratings were converted into actual pounds of lint cotton or bushels of grain sorghum per acre by the use of a computed factor.

Although the uses of percentage ratings and the method of least squares to obtain relative yields are not intended to supersede entirely the average actual yields, it is believed that these methods are valuable in an interpretation of the data and in the reaching of more definite conclusions than would be possible from the average actual yields alone.

METHODS OF CONDUCTING EXPERIMENT

These studies were made on cotton and grain sorghum (Hegari) on fairly large field plats, on a uniform soil classified as Miller loam. The two crops were grown in rotation so that cotton always followed grain sorghum and grain sorghum followed cotton. Varied amounts of water were measured in acre inches to the plats at various times.

[1] Mills, F. C. Statistical Methods, pages 432-441. Henry Holt & Co., New York. 1924.

Size and Replication of Plats

The plats consisted of five 3-foot rows 132 feet long, covering an area 15 feet wide and 132 feet long, equivalent to 1/22 acre. The three inside rows of each plat comprised the harvested area, equivalent to 3/110 acre. The two outside rows served as guard or border rows and were discarded at harvest time. The experiment consisted of eight different treatments which were replicated twice for both cotton and grain sorghum.

Earthen Borders

Each plat was surrounded by a high earthen border to retain the desired amount of irrigation water and to hold the rain that fell upon the plats. The land within these borders was graded to a level in order to obtain an even distribution of water throughout the plat.

Preparation of Seed Bed

All cotton and grain sorghum stalks were cut with a single-row stalk cutter, and on plats having a heavy growth of grain sorghum stalks it was necessary to re-cut a second and third time. The grain sorghum stubble was next up-rooted with a large sweep, after which the land was double disked thoroughly one to three times. The land was bedded early in December and re-bedded about the first of March. After the cotton stalks were cut, only one double disking was required to fit the land for bedding.

In order to secure an adequate moisture supply in the subsoil to a depth of 4 to 5 feet, a heavy pre-irrigation was applied two to three weeks before planting. As soon as the lister beds dried out sufficiently following the pre-irrigation, they were harrowed down almost level just prior to planting.

Planting

Cotton was planted practically on the level on lister beds with a single-row riding planter with a 16-inch solid sweep attached. The seed were covered about 1 inch deep and planted at the rate of 30 pounds per acre. The grain sorghum was planted slightly below the level on lister beds in a manner similar to that of the cotton. The seed were covered about 1½ inches deep at the rate of 8 to 10 pounds per acre.

Thinning

The cotton was thinned to single stalks 9 to 12 inches apart in the row when the plants had attained a heighth of 4 to 6 inches. Grain sorghum was thinned to single stalks 6 inches apart in the row when the plants were 2 to 3 inches high.

Cultivation

Cultivation for this experiment was similar to the cultivation given to all general field crops. Grain sorghum received three to five cultivations, and cotton received six to nine.

Irrigation

Since the irrigation for each crop in this experiment is different, it is mentioned in detail under the general discussion for each crop. The irrigation treatment varied with the crop, and was used in conjunction with the amount of water received from natural rainfall and the amount applied in the pre-irrigation of the seed bed. The total amount of water received by a plat is the sum of the pre-irrigation, the rainfall from the date of pre-irrigation to harvest date, and all irrigation water applied.

Fig. 2. Showing the method in irrigating plats. The plat in the center is receiving an irrigation of 4 acre-inches. The plat on the left has received 3 acre-inches, while the plat on the right has received 5 acre-inches.
A—Rectangular weir with 1-foot opening or notch.
B—Weir pond.
C—Weir gauge or measuring stake.
D—Levees or borders surrounding plats.

Method of Measuring Water

The irrigation water was measured directly to the plats through rectangular weirs placed at the head of each plat. The weirs were constructed with exactly a one-foot opening through which the water flowed directly onto the plat without any chance of loss of water due to seepage or evaporation.

Near each weir a measuring rule was located for the purpose of ascertaining the height of the head of water in the ditch, or still pond, adjacent to the weir. The height of the head of water regulates the quantity of water flowing through the weir notch, and the quantity of water was measured for each plat by the length of time it flowed.

Clyde (6) and Christiansen (7) describe the more common methods and devices used in measuring water for irrigation in California and Utah, with detailed explanations of terms used in measuring water, as well as of the principles of water measurement. The material in the main is a compilation of State and Federal data on this subject (Table 4).

Table 4. Discharge table for rectangular weirs

Head in inches	Discharge in cubic feet per second for crests of various length*				
	1 foot	1.5 feet	2 feet	3 feet	4 feet
2½	.312	.472	.632	.954	1.28
2⅝	.335	.505	.677	1.02	1.37
2¾	.358	.539	.723	1.09	1.46
2⅞	.380	.574	.769	1.16	1.55
3	.404	.609	.817	1.23	1.65
3⅛	.428	.646	.865	1.31	1.75
3¼	.452	.682	.914	1.38	1.85
3⅜	.477	.720	.965	1.46	1.95
3½	.502	.758	1.02	1.53	2.05
3⅝	.527	.796	1.07	1.61	2.16
3¾	.553	.836	1.12	1.69	2.26
3 13/16	.580	.876	1.18	1.77	2.37
3 15/16	.606	.916	1.23	1.86	2.48
4 1/16	.634	.957	1.28	1.94	2.60
4 3/16	.661	.999	1.34	2.02	2.71
4 5/16	.688	1.04	1.40	2.11	2.82
4 7/16	.717	1.08	1.45	2.20	2.94
4 9/16	.745	1.13	1.51	2.28	3.06
4 11/16	.774	1.17	1.57	2.37	3.18
4 15/16	.833	1.26	1.69	2.55	3.42
5 1/16	.863	1.30	1.75	2.65	3.54
5 3/16	.893	1.35	1.81	2.74	3.67
5¼	.924	1.40	1.88	2.83	3.80
5⅜	.955	1.44	1.94	2.93	3.93
5½	.986	1.49	2.00	3.03	4.05

*Computed from Cone's formula.

From Table 4, giving data on amount of water discharged from rectangular weirs, the amounts of water required for the plats in this study were computed, as shown in Tables 5 and 6. The head or crest of water is given in inches and the time of flow is given in minutes and seconds for each required depth of water from 1 to 6 acre inches. The flow of water was timed by use of a watch or stop-watch.

IRRIGATION OF COTTON

Adequate moisture was supplied to penetrate the soil to a depth of 4 to 5 feet before planting, by the method referred to as pre-irrigation. Pre-irrigation was necessary for years with deficient rainfall during March and April. During the early growing period of cotton, only relatively small amounts of water were applied, in order to produce slow-growing, healthy plants having deep rooting systems. At the beginning of the blooming and fruiting period of the plant, applications of irrigation water were greatly increased in an attempt to supply sufficient water to meet the full requirements of the plants for normal growth and production. Water was applied in amounts of 2, 8, 12, 15, 16, and 18 acre inches to cotton, in addition to the amount received as pre-irrigation of the seed bed and from rainfall during the growing season of the crop.

Irrigation Schedule

1. No irrigation. (Dry-land farming practice).
2. No pre-irrigation of seed bed. Irrigation of crop according to best judgment. First irrigation delayed until cotton shows suffering.
3. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. No further irrigations.
4. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. Irrigate the crop with 2 acre inches water applied 50, 80, 110, and 140 days from date of pre-irrigation of seed bed. (Total 8 acre inches).
5. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. Irrigate the crop with 3 acre inches water applied 50, 80, 110, and 140 days from date of pre-irrigation of seed bed. (Total 12 acre inches).
6. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. Irrigate the crop with 4 acre inches water applied 50, 80, 110, and 140 days from date of pre-irrigation of seed bed. (Total 16 acre inches).

Table 5. Acre F 21-30, size of plats, 1/17 acre

Head on crest, inches	Time required to discharge irrigation water, acre inches per plat											
	1 inch		2 inches		3 inches		4 inches		5 inches		6 inches.	
	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec
2½	11	24	22	48	34	12	45	36	57	0	68	24
2¾	9	56	19	52	29	48	39	44	49	40	59	36
3	8	49	17	38	26	27	35	16	44	5	52	54
3¼	7	52	15	44	23	36	31	28	39	20	47	12
3½	7	5	14	10	21	15	28	20	35	25	42	30
3¾	6	26	12	52	19	18	25	44	32	10	38	36
4 1/16	5	37	11	14	16	51	22	28	28	5	33	42
4 7/16	4	58	9	56	14	54	19	52	24	50	29	48
4 11/16	4	36	9	12	13	48	18	24	23	0	27	36
5 1/16	4	7	8	14	12	21	16	28	20	35	24	42
5¼	3	51	7	42	11	33	15	24	19	15	23	6
5½	3	37	7	14	10	51	14	28	18	5	21	42

Table 6. Acre G 21-30, size of plats, 1/18 acre

Head on crest, inches	Time required to discharge irrigation water, acre inches per plat											
	1 inch		2 inches		3 inches		4 inches		5 inches		6 inches	
	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
2½	10	46	21	32	32	18	43	4	53	50	64	36
2¾	9	23	18	46	28	9	37	32	46	55	56	18
3	8	19	16	38	24	57	33	16	41	35	49	54
3¼	7	26	14	52	22	18	29	44	37	10	44	36
3½	6	42	13	24	20	6	26	48	33	30	40	12
3¾	6	5	12	10	18	15	24	20	30	25	36	30
4 1/16	5	18	10	36	15	54	21	12	26	30	31	48
4 7/16	4	41	9	22	14	3	18	44	23	25	28	6
4 11/16	4	21	8	42	13	3	17	24	21	45	26	6
5 1/16	3	54	7	48	11	42	15	36	19	30	23	24
5¼	3	38	7	16	10	54	14	32	18	10	21	48
5½	3	25	6	50	10	15	13	40	17	5	20	30

7. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. Irrigate the crop with 5 acre inches water applied 50, 80, and 110 days after irrigation of seed bed. (Total 15 acre inches).
8. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. Irrigate the crop with 6 acre inches water applied 50, 80, and 110 days after irrigation of seed bed. (Total 18 acre inches).

Each plat was equipped with a 1-foot opening rectangular weir, located in the main canal, through which the water was measured directly to the plats without any loss, as shown in Figure 3.

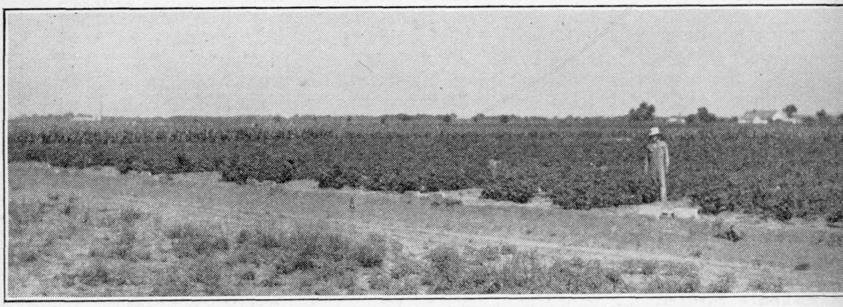

Fig. 3. Showing arrangement of cotton plats with levees and borders between plats, head irrigation ditch, with measuring weirs set at head of each plat.

Results Obtained in 1932

The season of 1932 was favorable for cotton production, because fully one-third of the total annual rainfall occurred during the first four months of the year, which gave an ample supply of soil moisture. It was not necessary, therefore, to give a pre-irrigation to the seed bed before planting. The season was practically normal in temperature, but the evaporation was high for July and low for August, which prevented heavy loss of soil moisture during the August fruiting period of the crop. The total water received by the cotton included all rainfall and irrigation water applied from planting date, May 26, to picking date, September 26, a period of 123 days.

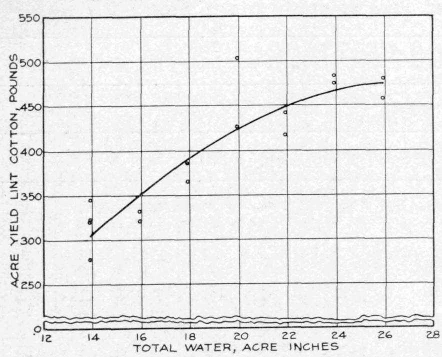

Fig. 4. Curve fitted to the yield of lint cotton in pounds per acre in 1932.

The application of 23.98 acre inches of water gave the highest yield, 486 pounds of lint per acre, (Table 7,) and the curve, (Figure 4,) indicates that approximately 24 inches of water was the optimum for 1932. The curve, with a computed correlation index of .912, shows a high positive correlation between the amount of water applied and yields obtained. The data also show that the increase

Table 7. Yield of cotton receiving different amounts of water, 1932

No. irrigations	Total		% Lint	Acre yield lint, pounds
	Irrigation water applied, acre inches	Rainfall and irrigation water, inches		
0	0	13.98	33.1	306
1	2	15.98	32.5	328
0	0	13.98	32.7	337
2	4	17.98	32.5	379
2	6	19.98	32.7	473
2	8	21.98	32.1	428
2	10	23.98	32.5	486
2	12	25.98	32.1	468

in yield was practically constant for a given increase in the amount of water up to 24 inches and dropped off for the next water level, 26 acre inches.

Results Obtained in 1933

The season of 1933 was fairly dry, accompanied by a large shortage of subsoil moisture; therefore, much larger quantities of water were required to reach the peak of production than were required in 1932. A pre-irrigation of 3 acre inches was given the seed bed on April 20, 8 days before the cotton was planted. The total rainfall was only 26.05 inches in 1933, as compared with the 11-year average of 30.14 inches. The rainfall was fairly well distributed throughout the growing season, with the heaviest occurring in March, May, and August. The rainfall during the other months was far below normal. The season was about normal with respect to evaporation and slightly above normal in mean temperatures. The total water received by the cotton includes all rainfall and irrigation water applied from the date of pre-irrigation, April 20, to picking date, September 26, a period of 159 days.

The highest yield of cotton, 413 pounds of lint per acre, was obtained from the use of 33.11 inches of water, as shown in Table 8. A curve was fitted to the yields in the table which is shown as Figure 5. This curve shows clearly a high positive correlation between the yield of cotton and the amounts of water applied. The correlation index was .858. Although the highest actual yield was obtained from 33.11 inches of water, the curve indicates that the peak of production would be near 35 or 36 acre inches.

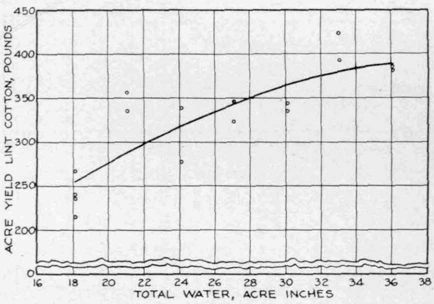

Fig. 5. Curve fitted to the yield of lint cotton in pounds per acre in 1933.

Table 8. Yield of cotton receiving different amounts of water, 1933

No. irrigations	Total		% Lint	Acre yield lint, pounds
	Irrigation water applied, acre inches	Rainfall and irrigation water, inches		
1	3	18.11	31.4	239
3	7	21.11	32.1	344
1	3	18.11	31.4	232
4	9	24.11	32.1	306
4	12	27.11	32.7	339
4	15	30.11	32.7	346
4	18	33.11	32.7	413
4	21	36.11	32.1	385

Results Obtained in 1934

The total annual rainfall in 1934 was only 24.70 inches, or 5.44 inches below normal. The months of heaviest rainfall were March, August, and November. All other months were considerably below normal and, because of rather unfavorable weather conditions, the yield of cotton was reduced greatly. On account of an extremely dry winter and spring, a pre-irrigation of 3 acre inches was necessary to supply sufficient soil moisture before planting. The mean temperature for the season was slightly above the normal, and it was accompanied by exceedingly high evaporation, both factors causing the high amount of water necessary for normal crop production. The amount of water applied apparently did not exceed the amount required for maximum production, and it is doubtful that the optimum water requirement for cotton was reached this season. The total water received by the cotton included all rainfall and irrigation water applied from the date of pre-irrigation, April 21, to the picking date, September 30, a period of 162 days.

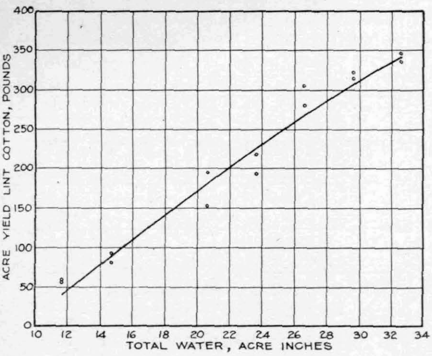

Fig. 6. Curve fitted to the yield of lint cotton in pounds per acre in 1934.

The largest yield of cotton, 345 pounds of lint per acre, was obtained from the plats that received the most water (Table 9). A curve fitted to these yields (Figure 6) shows a very high positive correlation between the amount of water applied and yields. The correlation index was .996. It will be noted that the yields continued to increase as the amount of water was increased, and that the application of water this year did not reach the optimum. The curve, however, indicates that the optimum amount of water was perhaps within the range of 33 and 35 acre inches.

Table 9. Yield of cotton receiving different amounts of water, 1934

No. irrigations	Total: Irrigation water applied acre inches	Total: Rainfall and irrigation water, inches	% Lint	Acre yield lint, pound
0	0	11.63	32.5	52
4	11	22.63	35.9	181
1	3	14.63	36.1	87
4	9	20.63	35.9	175
4	12	23.63	36.5	211
4	15	26.63	36.3	297
4	18	29.63	35.9	320
4	21	32.63	36.1	345

Results Obtained in 1935

The seasonal conditions in 1935 were favorable for cotton production and with respect to rainfall approach closely those in 1932. The total precipitation was slightly above normal and was well distributed throughout the growing season. The late winter and early spring months were very dry and a pre-irrigation of 3 acre inches on April 24 was necessary to put the seed bed in good condition for planting. On account of excessive rainfall throughout May, the test was not planted until May 30. The total water received by the cotton included all rainfall and irrigation water applied from the date of pre-irrigation, April 24, to the height of the picking season, October 10, a period of 169 days. The season was normal in temperatures, with lower total evaporation than normal. Fully two-thirds of the annual rainfall, or a total of 21.51 inches, occurred during the growing season, and accounts for the narrow fluctuation in yields. It is evident that with such variations in seasons in this area seasonal influence is an important factor where irrigation is practiced.

Table 10. Yield of cotton receiving different amounts of water, 1935

No. irrigations	Total: Irrigation water applied, acre inches	Total: Rainfall and irrigation water, inches	% Lint	Acre yield lint, pounds
1	0	21.51	35.2	219
3	8	29.51	37.1	265
1	3	24.51	37.1	234
3	7	28.51	36.5	260
3	9	30.51	36.5	273
3	11	32.51	36.5	254
3	13	34.51	36.5	277
3	15	36.51	36.7	257

It will be noted from Table 10 that an application of 34.51 acre inches of water gave the highest yield. There was a gradual falling off in yields as the amount of water was increased beyond this amount. The curve in Figure 7 shows a very narrow range in yields at different water levels, and the correlation is much lower than in previous years. The correlation index value was only .765 and the curve flattened out in a more horizontal direction. The data indicate that approximately 30 to 32 acre inches was the optimum amount of water in 1935. The decrease in yield from this point is so small that it is not significant and cannot be measured when the strict statistical interpretation is applied.

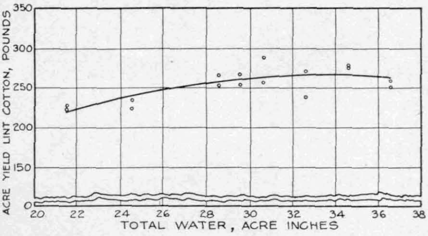

Fig. 7. Curve fitted to the yield of lint cotton in pounds per acre in 1935.

Results Obtained in 1936

The seasonal conditions during 1936 were very unfavorable for cotton where irrigation was not practiced, and all upland cotton surrounding the irrigated valley was almost a complete failure. The year was the driest on record at this station for the 11-year period 1926-36, inclusive, with a total rainfall of only 23.36 inches. The temperatures were extremely high, with a new maximum absolute temperature of 112 degrees in August, which was 5 degrees higher than the previous maximum of 107 degrees. The extreme high temperatures, together with normal evaporation, caused heavy losses in soil moisture throughout the growing period of the crop. The total water received by the cotton includes all rainfall and irrigation water applied from the date of pre-irrigation, April 24, to the beginning of the picking period, September 8, a period of 132 days.

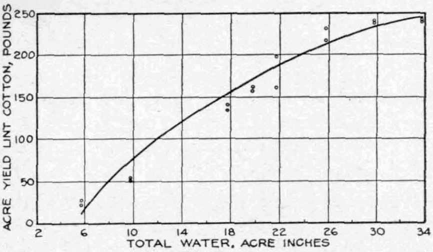

Fig. 8. Curve fitted to the yield of lint cotton in pounds per acre in 1936.

The application of 29.74 acre inches of water gave the highest yield, 246 pounds of lint per acre (Table 11). A curve (Figure 8) fitted to the yields in Table 11 shows a very high positive correlation between the amount of water applied and yield, as indicated by the correlation index value of .982. The curve indicates that the optimum water requirement was between 28 and 33 acre inches. It is evident that where irrigation is practiced as a supplement to rainfall, seasonal influence is a factor which will cause very wide differences in yields from year to year independent of irrigation.

Table 11. Yield of cotton receiving different amounts of water, 1936

No.	Total		% Lint	Acre yield lint, pounds
	Irrigation water applied, acre inches	Rainfall and irrigation water, inches		
0	0	5.74	33.3	24
1	4	9.74	35.4	54
4	14	19.74	35.0	156
5	12	17.74	34.2	146
5	16	21.74	35.0	182
5	20	25.74	35.0	227
5	24	29.74	35.7	246
5	28	33.74	35.7	244

Discussion of Results

The results obtained in individual years have been discussed separately in the preceding pages. In order to provide a better idea of the experiment as a whole, the results obtained in each of the five years are brought together in Table 12. From these data it will be seen that the use of 30.19 inches of water produced the largest average yield of cotton, 348 pounds of lint per acre. The yield decreased as the amount of water was increased or decreased from 30.19 inches. Thus, the use of 32.99 acre inches of water produced 340 pounds of lint per acre, while 27.39 inches produced only 310 pounds. These figures indicate that the optimum amount of water for cotton is about 30 acre inches.

In order to show more definitely the relation of amounts of water and yield of cotton, a curve was fitted to the average yields of cotton given in the table (Figure 9). The highest point of this curve occurs at 30 acre inches of water. This fact indicates that approximately 30 acre inches is the optimum amount of water for cotton under average conditions in the irrigated valley, although there was not much difference in yields where the amount of water ranged from 28 to 32 inches.

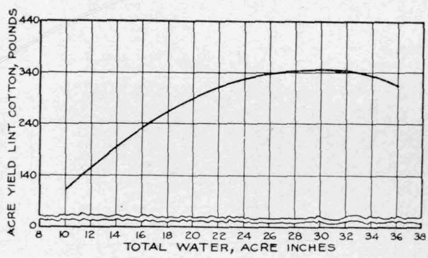

Fig. 9. Curve fitted to the average yield of lint cotton per acre for the 5-year period 1932-1936.

The amount of water required, however, may vary from season to season. In 1932 the rainfall during the growing season was 13.98 inches (Table 13). The largest yield of cotton was obtained by adding 10 inches of irrigation water, making a total of 23.98 acre inches of water. In 1933, with 15.11 inches of rainfall during the active growing season, the application of 18 inches of irrigation made the largest average yield, 413 pounds of lint per acre. Thus, there was a difference of about 9 inches in the optimum amount of

Table 12. Average yield of cotton receiving different amounts of water, 1932-1936

Acre inches											Acre yield lint, pounds					
Total irrigation water applied					Total all irrigation water and natural rainfall											
1932	1933	1934	1935	1936	1932	1933	1934	1935	1936	Aver.	1932	1933	1934	1935	1936	Aver.
0	3	0	0	0	13.98	18.11	11.63	21.51	5.74	14.19	306	239	52	219	24	168
2	7	11	8	4	15.98	21.11	22.63	29.51	9.74	19.79	328	344	181	265	54	234
0	3	3	3	14	13.98	18.11	14.63	24.51	19.74	18.19	337	232	87	234	156	209
4	9	9	7	12	17.98	24.11	20.63	28.51	17.74	21.79	379	306	175	260	146	253
6	12	12	9	16	19.98	27.11	23.63	30.51	21.74	24.59	473	339	211	273	182	296
8	15	15	11	20	21.98	30.11	26.63	32.51	25.74	27.39	428	346	297	254	227	310
10	18	18	13	24	23.98	33.11	29.63	34.51	29.74	30.19	486	413	320	277	246	348
12	21	21	15	28	25.98	36.11	32.63	36.51	33.74	32.99	468	385	345	257	244	340

Table 13. Available rainfall in inches for the growing season of cotton, by months, for the 5-year period, 1932-1936

Month	1932	1933	1934	1935	1936	Average
April	0	0	.27	.44	0	.14
May	.50	7.82	2.93	9.70	3.69	4.93
June	2.73	.25	1.42	4.40	.67	1.89
July	3.09	.28	.48	1.93	.85	1.33
August	5.19	5.98	2.40	1.07	0	2.93
September	2.47	.78	4.13	3.63	.53	2.31
October	0	0	0	.34	0	.07
Total	13.98	15.11	11.63	21.51	5.74	13.60

water during the two years. Further, in 1934, with 11.63 inches of rain during the growing season from April to October, the use of 21 inches of irrigation water gave the best results. In 1935, when the rainfall during the growing season was 21.51 inches, the largest yield of cotton was obtained by applying 13 inches of irrigation water, which made a total of 34.51 acre inches of water. By comparing the optimum of 23.98 inches in 1932 with the optimum of 34.51 inches in 1935, we find a difference of 10.53 inches required for maximum yield of cotton in different years. These differences are due in part to differences in amount and distribution of rainfall, humidity, evaporation, and temperature.

IRRIGATION OF GRAIN SORGHUM

The method of irrigating sorghum was similar to the method used for cotton. The amounts of water, however, were increased and the interval between irrigations was reduced to 20 days (Figure 10). Water was applied in total amounts of 8, 12, 16, 20, and 24 acre inches, in conjunction with the amount received from rainfall and from the pre-irrigation of the seed bed.

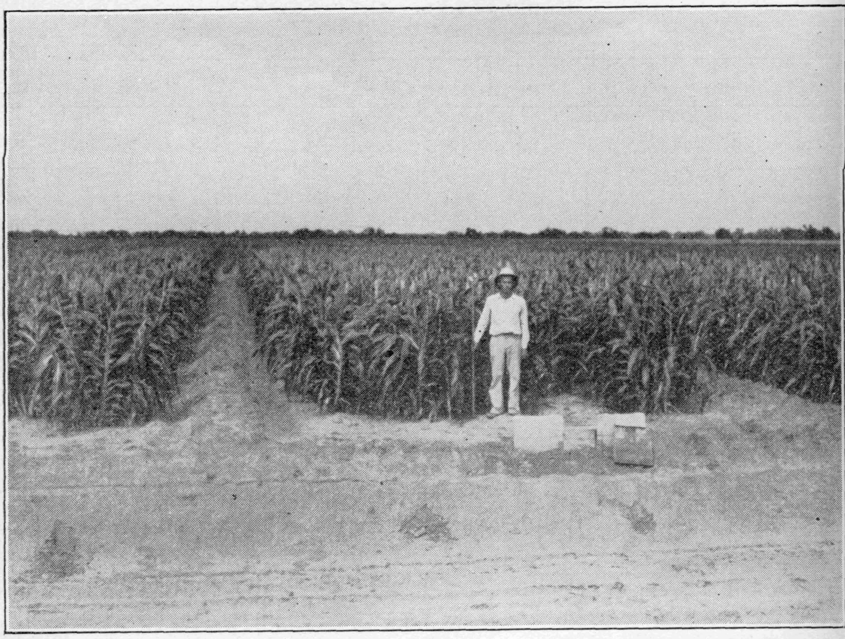

Fig. 10. Showing plat arrangement of grain sorghum, with borders between plats. Head irrigation ditch with measuring weir in foreground.

Irrigation Schedule

1. No irrigation. (Dry-land farming practice).
2. No pre-irrigation of seed bed. Irrigation of crop according to best judgment. First irrigation delayed until the crop shows suffering.
3. Pre-irrigation of seed bed sufficient to sature the soil to a a depth of 4 to 5 feet. No further irrigation.
4. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. Irrigate the crop with 2 acre inches water, applied 40, 60, 80, and 90 days from date of pre-irrigation of seed bed. (Total 8 acre inches).
5. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. Irrigate the crop with 3 acre inches water, applied 40, 60, 80, and 90 days from date of pre-irrigation of seed bed. (Total 12 acre inches).
6. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. Irrigate the crop with 4 acre inches water, applied 40, 60, 80, and 90 days from date of pre-irrigation of seed bed. (Total 16 acre inches).
7. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. Irrigate the crop with 5 acre inches water, applied 40, 60, 80, and 90 days from date of pre-irrigation of seed bed. (Total 20 acre inches).
8. Pre-irrigation of seed bed sufficient to saturate the soil to a depth of 4 to 5 feet. Irrigate the crop with 6 acre inches water, applied 40, 60, 80, and 90 days from date of pre-irrigation of seed bed. (Total 24 acre inches).

Results Obtained in 1932

The season of 1932, with a total precipitation of 33.09 inches, was very favorable for grain sorghum. An abundance of rainfall occurred during the spring months and it was not necessary to pre-irrigate the seed bed before planting. The season was practically normal in temperatures. The evaporation was high for July but low for August because of an abundance of rainfall during the month, followed by cool, cloudy periods, favorable for grain production. The total water received by the crop includes all rainfall and irrigation water applied from the date of planting, May 26, to the harvest date, October 20, a period of 148 days.

The application of 32.58 acre inches of water gave the highest yield, as shown in Table 14. This was the largest amount of water in 1932, and it is evident that the optimum water requirement for normal production was greater than 32.58 inches. The curve (Figure 11) shows a very close relationship between the amount of water applied and yields, with a correlation index of .899.

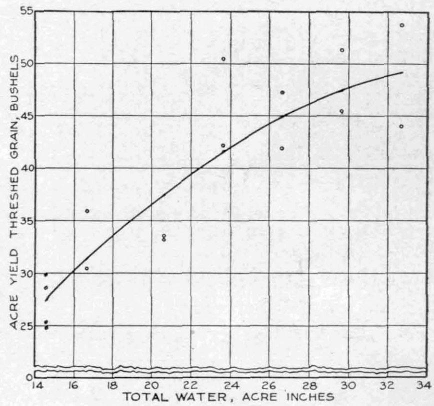

Fig. 11. Curve fitted to the yield of grain sorghum in bushels per acre in 1932.

Although the results in Table 11 show that not enough water was applied to produce maximum yields, the curve indicates that the peak of production would occur at about 34 inches of water.

Table 14. Yield of grain sorghum receiving different amounts of water, 1932

No. irrigations	Total: Irrigation water applied, acre inches	Total: Rainfall and irrigation water, inches	Acre yield threshed grain, bushels
0	0	14.58	27.3
1	2	16.58	33.2
3	6	20.58	33.2
3	9	23.58	46.1
3	12	26.58	42.9
3	15	29.58	48.4
3	18	32.58	48.8

Results Obtained in 1933

The season of 1933 was dry, with a rainfall of only 26.05 inches. The year, however, was favorable for grain production and slightly higher yields were secured than in 1932. The early spring months were exceedingly dry and it was necessary to pre-irrigate the seed bed before planting. The season was slightly above normal in temperatures, although the total evaporation was practically normal. Heavy precipitation of 5.98 inches in August was beneficial to the crop and no irrigations were given for the month. The total amount of water received by the crop includes all rainfall and irrigation water applied from the date of pre-irrigation, April 20, to harvesting date, August 23, a period of 135 days.

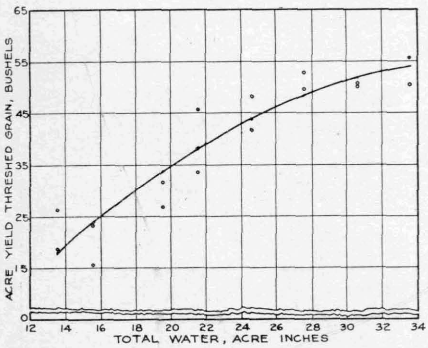

Fig. 12. Curve fitted to the yield of grain sorghum in bushels per acre in 1933.

The application of 33.61 inches of water, which was the largest amount used in 1933, gave the highest yield of grain sorghum (Table 15). The curve (Figure 12), which was fitted to the yields in this table, shows a high positive correlation between yields and amounts of water used. The correlation index was .937. Further, the curve indicates that not enough water was applied to produce maximum yields, and that the peak of production probably would have occurred at 34 or 35 inches of water.

Table 15. Yield of grain sorghum receiving different amounts of water, 1933

No. irrigations	Total		Acre yield threshed grain, bushels
	Irrigation water applied, acre inches	Rainfall and irrigation water, inches	
1	1	13.61	22.4
1	3	15.61	19.4
3	7	19.61	29.4
4	9	21.61	39.8
4	12	24.61	45.2
4	15	27.61	51.4
4	18	30.61	51.0
4	21	33.61	53.2

Results Obtained in 1934

The season of 1934 was exceedingly dry, with a total precipitation of only 24.70 inches. The season was very unfavorable for the production of grain, because of extreme high temperatures and evaporation during July and August. These conditions apparently forced the crop into a semi-dormant condition which retarded booting and heading of the crop fully 40 days. With irrigation, the crop did not suffer for lack of water, but remained green and succulent during the dry, hot months. Finally, late in September, following rain and cooler weather, the crop headed and matured only a fair yield of grain. Grain sorghum on check plats, which received no irrigation water, withered down to mere stubs during

August, but recuperated late in September and matured a fair yield of grain. The total water received by the crop included all rainfall and irrigations from the date of pre-irrigation, April 21, to harvesting date, October 15, a period of 177 days.

The application of 30.79 acre inches of water gave the highest yield (Table 16). When the water was increased to 38.79 inches, the yields were reduced significantly. The curve in Figure 13 shows a close relationship between the amounts of water applied and yields, with a correlation index value of .941. It is evident that the optimum water requirement for grain sorghum ranged between 30 and 35 acre inches, and the curve indicates that the peak of production was reached and passed in terms that can be considered significant.

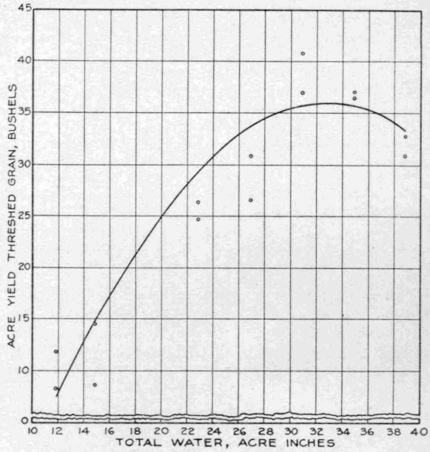

Fig. 13. Curve fitted to the yield of grain sorghum in bushels per acre in 1934.

Table 16. Yield of grain sorghum receiving different amounts of water, 1934

No. irrigations	Total		Acre yield threshed grain, bushels
	Irrigation water applied, acre inches	Rainfall and irrigation water, inches	
0	0	11.79	10.0
1	3	14.79	11.7
4	13	24.79	36.4
5	11	22.79	28.2
5	15	26.79	28.9
5	19	30.79	38.9
5	23	34.79	36.9
5	27	38.79	32.0

Results Obtained in 1935

The season of 1935, with a total rainfall of 32.50 inches, was favorable for grain sorghum. Practically two-thirds of the annual rainfall, 22.33 inches occurring during the growing season, was available for crop production. The spring months, however, were unusually dry and it was necessary to pre-irrigate the seed bed before planting. Heavy rainfall occurred early in May, which delayed planting of the grain sorghum in the test until May 28. The temperature was practically normal, although the evaporation was 9 inches below normal and ranged from 10 to 13 inches less than in the three preceding years. The total water received by the crop included all rainfall and irrigation applied from the date of pre-irrigation, April 13, to the date of harvest, October 15, a period of 185 days. There was a delay of 25 days in planting this year, although the crop matured normally under the favorable weather conditions which prevailed throughout the crop season.

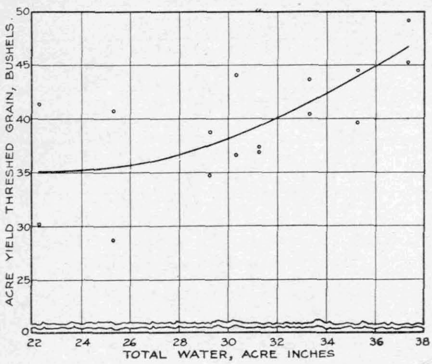

Fig. 14. Curve fitted to the yield of grain sorghum in bushels per acre in 1935.

The application of 37.33 acre inches of water gave the highest yield of grain, although the optimum water level was evidently not reached this year (Table 17). The curve (Figure 14) shows a positive correlation between the total amounts of water and yields. The correlation, however, was not as high as in the preceding years, as indicated by the correlation index value of .6804. The curve indicates that a range between 33 and 38 acre inches was the optimum water requirement for sorghum in 1935.

Table 17. Yield of grain sorghum receiving different amounts of water, 1935

No. irrigations	Total		Acre yield threshed grain, bushels
	Irrigation water applied, acre inches	Rainfall and irrigation water, inches	
0	0	22.33	36.1
1	3	25.33	34.9
3	7	29.33	37.0
3	8	30.33	40.6
3	9	31.33	37.5
3	11	33.33	44.9
3	13	35.33	42.4
3	15	37.33	47.6

Results Obtained in 1936

The season of 1936 was the driest year on record at this station, with an annual precipitation of only 23.35 inches, which was unfavorable for grain sorghum. The seasonal influence on the growth of grain sorghum was similar to the dry year of 1934, in that the crop was thrown into a semi-dormant state of growth early in August, and failed to boot and produce heads until late in September, following rain and cooler weather. It was observed in both years, 1934 and 1936, that the grain sorghum became dormant because of extremely clear, hot, dry weather accompanied by low humidity, excessive evaporation, and an occasional hot wind. The crop in this dormant state failed to respond to the large amounts of irrigation water supplied during such periods. It is evident that seasonal influences, especially high temperatures and excessive evaporation, which increase transpiration of moisture from the plants, are factors responsible for the dormancy during such abnormal years.

Hegari, the variety of grain sorghum used in this test, has high potentialities under irrigation but is erratic in behavior to abnormal climatic and seasonal influences.

The application of 51.77 acre inches of water, the largest amount used in 1936, made the best yield of grain sorghum (Table 18). The yield, however, was low as compared with the yields obtained in the four preceding years. Although the conditions were quite unfavorable for grain sorghum, there was a high positive correlation between yield of grain and the amounts of water used, as shown by the curve in Figure 15. The correlation index was .998. It is evident that, under the peculiar conditions that prevailed in 1936, the optimum water requirement was not reached this season.

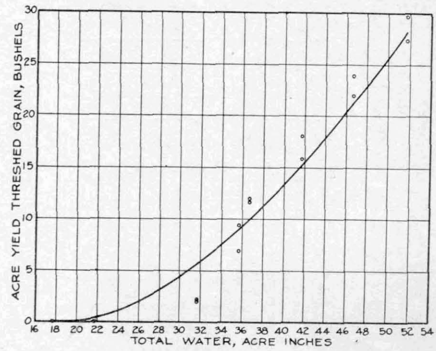

Fig. 15. Curve fitted to the yield of grain sorghum in bushels per acre in 1936.

Table 18. Yield of grain sorghum receiving different amounts of water, 1936

No. irrigations	Total		Acre yield threshed grain, bushels
	Irrigation water applied, acre inches	Rainfall and irrigation water, inches	
0	0	17.77	0
5	18	35.77	8.1
1	4	21.77	0
6	14	31.77	2.1
6	19	36.77	11.8
6	24	41.77	17.0
6	29	46.77	23.0
6	34	51.77	26.1

Discussion of Results

The results obtained during the five years, 1932-36, are assembled in Table 19 and averaged in order to provide a more comprehensive view of the experiment as a whole. These data indicate that the yield of sorghum increased as the amount of irrigation was increased and that the average optimum amount of water, as far as yield is concerned, was not reached in these studies. The increases in yield produced by additional amounts of water, however, become smaller at the larger applications of water. These facts indicate that the optimum amount of water on the average probably would be about 39 inches. Satisfactory yields, however, were obtained within the range of 32 to 39 acre inches.

Table 19. Average yield of grain sorghum receiving different amounts of water, 1932-1936

Acre inches											Acre yield threshed grain, bushels					
Total irrigation water applied					Total all irrigation water and natural rainfall											
1932	1933	1934	1935	1936	1932	1933	1934	1935	1936	Aver.	1932	1933	1934	1935	1936	Aver.
0	1	0	0	0	14.58	13.61	11.79	22.33	17.77	16.02	29.5	22.4	10.0	36.1	0	19.6
2	7	13	8	18	16.58	19.61	24.79	30.33	35.77	25.42	33.2	29.4	36.4	40.6	8.1	29.5
0	3	3	3	4	14.58	15.61	14.79	25.33	21.77	18.42	25.0	19.4	11.7	34.9	0	18.2
6	9	11	7	14	20.58	21.61	22.79	29.33	31.77	25.22	33.2	39.8	28.2	37.0	2.1	28.1
9	12	15	9	19	23.58	24.61	26.79	31.33	36.77	28.62	46.1	45.2	28.9	37.5	11.8	33.9
12	15	19	11	24	26.58	27.61	30.79	33.33	41.77	32.02	42.9	51.4	38.9	44.9	17.0	39.0
15	18	23	13	29	29.58	30.61	34.79	35.33	46.77	35.42	48.4	51.0	36.9	42.4	23.0	40.3
18	21	27	15	34	32.58	33.61	38.79	37.33	51.77	38.82	48.8	53.2	32.0	47.6	26.1	41.5

A parabolic curve was fitted to the yields in Table 19 in order to show more clearly the relationship between the yield of grain sorghum and the amounts of water used (Figure 16). This curve shows that the average yield increased as the amount of water was increased. Further, the curve indicates that 38 to 40 inches is probably the optimum amount of water for grain sorghum under the conditions prevailing in the Wichita Valley Irrigation District. Since the average rainfall during the growing season of sorghum is about 16 inches (Table 20), and the crop needs about 39 inches of water, it is obvious that approximately 23 acre inches of water should be given in suitable irrigations.

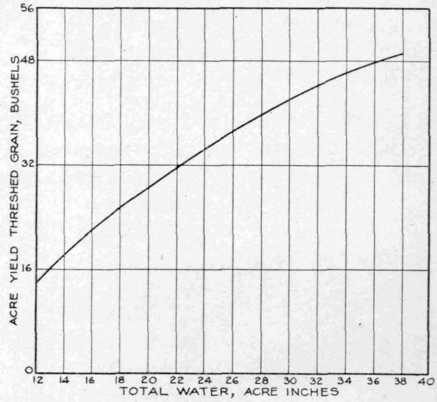

Fig. 16. Curve fitted to the average yields of grain sorghum per acre for the 5-year period 1932-1936.

Under the hot, dry conditions that prevailed in the Wichita Valley in 1934 and 1936, Hegari, the variety of grain sorghum used, became more or less dormant and did not respond readily to irrigation until cooler weather in September.

Table 20. Available rainfall for the growing season of grain sorghum, by months, for the 5-year period, 1932-1936

Month	1932	1933	1934	1935	1936	Average
April	0	0	.27	1.26	0	.31
May	.50	7.82	2.93	9.70	3.69	4.93
June	2.73	.25	1.42	4.40	.67	1.89
July	3.09	.28	.48	1.93	.85	1.33
August	5.19	4.26	2.40	1.07	0	2.58
September	2.49	0	4.13	3.63	12.56	4.56
October	.58	0	.16	.34	0	.22
Total	14.58	12.61	11.79	22.33	17.77	15.82

SUMMARY

Experiments were begun in 1932 at Texas Substation No. 16, located at Iowa Park, in the Wichita Valley, Texas, to determine the irrigation requirements of cotton and grain sorghum. The rate of irrigation ranged from 2 to 34 acre inches. The studies were conducted on Miller loam soil and extended over a period of five years, 1932-36.

During the five years the highest average yield of cotton was obtained from the use of 30 acre inches of water, which included both irrigation and rainfall during the growing season of the crop. The yield declined as the amount of water was increased or diminished from 30 inches. From the practical standpoint, however, good yields were obtained where the amounts of water ranged from 28 to 32 acre inches.

The results obtained with grain sorghum indicate that approximately 38 to 39 acre inches is the optimum amount of water for the crop under the conditions prevailing in the Wichita Valley. Good yields, however, were obtained from amounts of water ranging from 32 to 39 inches. During the hot, dry seasons of 1934 and 1936, the crop did not respond as readily to irrigation as in more favorable years.

The results obtained with both cotton and grain sorghum indicate that the total amount of water required for maximum yields is influenced by seasonal conditions, which include the amount and distribution of rainfall, humidity, and temperature. In general, the results indicate that these crops need more water in dry, hot years than in years with more favorable conditions.

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